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2 October 1980

USSR Report

ELECTRONICS AND ELECTRICAL ENGINEERING

(FOUO 15/80)

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COMMUNICATIONS, COMMUNICATION EQUIPMENT, RECEIVERS AND TRANSMITTERS, NETWORKS, RADIO PHYSICS, DATA TRANSMISSION AND PROCESSING, INFORMATION THEORY

LINE DISTRIBUTION BAY SLK-2 DESCRIBED

Moscow ELEKTROSVYAZ' in Russian No 5, 1980 p 59

[Article by A. L. Prasolov and S. M. Vorob'yeva]

[Text] The line distribution bay SLK-2 is intended for operational switching between a line distribution frame and the Central Wire Broadcasting Station, as well as for measuring connecting lines and checking the condition of the cells of supply feeder bays (SPF-2) and output switching and control bays (SVKU). SLK-2 bay is a modernized version of the SLK-1 bay. It has a cell connection circuit, a built-in resistance indicator, and a wider measuring range for flow-around currents in connecting lines.

The bay is designed as a standard cabinet without a framework. The wiring of the bay is accessible from the back side through a two-leaf door and through a protective panel in front. The front side of the bay has: a switching field consisting of duodecal jack frames; a set of monitoring and testing elements consisting of one cell for controlling and monitoring transformer substations intended for checking remote control by the switching equipment of supply feeders, one cell for controlling and monitoring repeater substations intended for checking the telecontrol system with the instruments on the units and the control panel which contains a flow-around current indicator and a resistance indicator, a pullout table for placing measuring instruments and recording, and a removable table for telephone sets.

All connecting lines enter the bay from below, are soldered to the frames with pins located on the back side, and then each line is connected with the frames with pins installed on the front side of the bay under the protective panel through parallel and break jacks. All types of communication are done through cords with three-wire plugs.

Specifications. Bay capacity: 640 connecting lines; 20 intermediate switching lines; 10 jacks for telephone communication; 20 two-wire shielded jacks for connecting various loads and signaling.

The bay makes it possible to measure loop resistance, insulation resistance, and resistance between each wire of the connecting line and the ground. The resistance measuring range is 0-1 kOhm, 0-10 kOhms, 0-1 MOhm. Provisions

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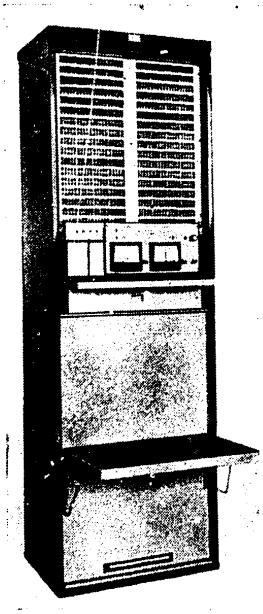
are made for monitoring the flow-around current in each wire of any connecting line within the limits of minus 10 ÷ plus 10 mA and minus 50 ÷ plus 50 mA. Crosstalk attenuation between any connecting lines of the bay is not less than 85 dB.



The bay has two compartments for control cells, which makes it possible to perform selective checking of the control systems of the equipment of repeater stations and transformer substations and to replace and check the control cells.

The control and monitoring cells draw current from: direct-current sources with positive ground (60 V±10%, 24 V±10%); with negative ground (60 V±10%); from a direct-current source insulated from the ground (60 V±10%; from a pulsating voltage source with positive ground (24 V±10%).

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The resistance indicator is operated from a direct current source of 60 V± 10% insulated from the ground.

The current consumption of the resistance indicator does not exceed 450 mA.

Bay dimensions: 2020 X 650 X 400 mm. Weight -- 200 kg.

Operating conditions: ambient air temperature -- from +10 to +40 degrees C: relative humidity -- up to 80% at 25 degrees C.

Designed by the Central Design Office of the USSR Ministry of Communication and the Moscow Municipal Wire Broadcasting Network.

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SUPPLY FEEDER BAY SPF-2 DESCRIBED

Moscow ELEKTROSVYAZ' in Russian No 5, 1980 p 60

[Article by I. L. Golubeva and S. M. Vorob'yeva]

[Text] The supply feeder bay SPF-2 is a part of the complex of the special purpose equipment of the Central Wire Broadcasting Station (TsSPV) of Moscow and is intended for distance control of the main-line (working and standby) feeders through which the voltage of broadcasting programs is delivered to transformer substations (TP), for monitoring their condition, as well as for receiving backward sound monitoring signals from the TP buses.

The SPF-2 was developed on the basis of modern elements to replace the SPF-1 bays operating at the present time.

The actuators of the SPF-2 bay are electronic relays designed as a circuit of triggers with additional symmetry using transistors of different conductance. The use of electronic relays increases considerably the sensitivity and reliability of the equipment and reduces the time of preventive maintenance and tuning of the equipment.

Each wire of the line of supply feeder control (UPF) is assigned to one of the supply feeders of a given TP. The switching of the feeder from the working state to the standby state and vice versa is accomplished by sending a short-duration voltage of -60 V to the appropriate wire of the UPF line; the monitoring of the condition of the feeder is accomplished by passing a direct current of 60 V around the appropriate wire of the UPF line differing in its value in the "work" state and "standby".

The bay is designed as a welded cabinet. It has the following: a signaling panel intended for sending supply voltages to the cells and signaling failures of supply voltages; the panel has control and signaling devices common for the entire bay and fuses; 60 draw-out control and monitoring cells of the transformer substations, the cells are removable; a panel with intermediate switching jacks is located under the cells.

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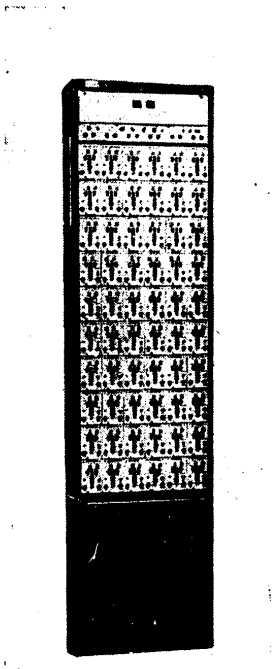

Four rotary panels of the relay for selective control and monitoring of TP from the panel of the operator on duty are located on the front and back sides of the lower part of the bay. The lower part of the bay contains also lead-in combs and supply blocks covered by jackets.

Specifications. The bay is intended for controlling 60 TP and serves the following purposes: remote switching of TP supply from one supply feeder to another; reception and decoding of signals regarding the state of the supply feeders ("operation", "standby", "failure"); reception of backward sound monitoring signals from each TP; switching the backward monitoring voltage to the technical control station by command from it; selective TP monitoring and control from the panel of the TsSPV operator on duty; transmission of the "on" and "off" commands of the fire alarm signaling system to TP; the possibility of transmitting commands from the technical monitoring equipment to TP without disturbing the signaling regarding the state of the supply feeders.

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Monitoring and control are accomplished via one connecting line between TsSPV and each TP. The resistance of each wire must not exceed three kilo-ohms. Crossover interference between any lines is not less than -- 85 dB in the frequency range of 50-10,000 Hz.

The bay is operated from a direct current source of -24 V±10%; +60 V±10%; -60 V±10%; -24 V pulsed.

Bay dimensions: 533 X 400 X 2000 mm. Weight -- 200 kg.

The bay is installed for operation at the TsSPV at a temperature of +10 to +40 degrees C and a relative humidity of up to 80% at a temperature of +25 degrees C.

Designed by the Central Design Office of the USSR Ministry of Communications and the Moscow Municipal Wire Broadcasting Network.

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SPECIAL CHARACTERISTICS OF THE MANUFACTURING TECHNOLOGY OF BIS FOR THE HARDWARE OF THE ASPI COMPLEX

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 5, 1980 pp 40-41

[Article by Candidates of Technical Sciences P. D. Tokarev and L. M. Khokhlov]

[Text] The low cost of the element base is the most important requirement for such mass-produced computing systems as electronic keyboard cash registers, billing and accounting machines and console-type data recorders combined into an integrated data collection and processing complex (ASPI [automated primary information processing system]). Due to a relatively low speed of the equipment of the ASPI complex, which is determined, chiefly, by the input time of the conditions and programs for solving problems, the designing of such equipment was done until recently with a wide use of universal integrated circuits (IS) using high-threshold MDP [metal-insulator-semiconductor] transistors (series K162 and K172; K501; K145, respectively, of low, medium, and high degrees of integration). However, it became clear that further improvement of economic indicators of the mass equipment of the ASPI complex can be achieved only by combining the development of this equipment with the creation of specialized functionally complete assemblies which are equivalent in their designs to large-scale integrated circuits (BIS) having as many as 1000 and more logical gates per case. By using them together with universal IS, it is possible to ensure the production of a wide range of hardware for the ASPI complex with a relatively small list of specialized assemblies.

There are two ways to solve this problem: either by the method of microassemblies (MS) with the use of caseless active elements on the basis of the above-mentioned IS series, or on the basis of BIS manufactured completely according to the semiconductor MDP technology.

The advantage of MS is the relative simplicity of their designing which amounts, chiefly, to the compilation of a circuit diagram and development of a filmy substrate mounting plate on the basis of the designing principles of two-sided printed-circuit cards. The equipment for producing MS consists, chiefly, of three devices: a vacuum spraying unit, a unit for thermocompression or ultrasonic welding of the terminals of caseless IS, and a unit for

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sealing the cases. At the same time, the labor input in the manufacturing of MS is equal to the labor input in mounting encased IS on printed plates, and their repairability is considerably lower. For this reason MS yielding a real gain only with respect to the size and weight characteristics of the products and not with respect to their cost did not find application in mass-produced equipment.

Semiconductor technology for the organization of series production of specialized BIS requires high initial capital investments amounting to many millions of rubles, development of complex technological processes -- precision photolithography, thermodiffusion, etc, as well as methods of design automation without which the development of complex BIS is practically impossible. However, all initial expenditures are justified by the great gains in the characteristics of the final product.

Calculations and practical experience confirm that the use of specialized MDP-BIS makes it possible to reduce greatly the dimensions, weight, labor input in the production, and costs of mass-produced hardware of the ASPI complex and improve its reliability at the same time. This determined the selection of the MDP technology for the manufacturing of the specialized element base for the mass production of the ASPI complex. Let us examine the special characteristics of the technology of specialized BIS in comparison with the technology of the production of IS series which formerly served as a basis in designing hardware for the ASPI complex and the ways of their realization.

Basic Character. Specialized BIS of all types must be manufactured according to the same operational documentation; exceptions can be caused only by differences in the number of external terminals of the cases and electrical control programs. The technology can allow for further development without affecting the compatibility of the production of BIS of new and earlier types.

In order to realize the basic character of the technology, a number of dimensional and electrical parameters of MDP-BIS elements were developed and checked experimentally which included such characteristics as layer-by-layer dimensions of the windows and areas for creating the elements of transistors and connecting bars, technological allowances in making phototemplates and structures on silicon plates, specific values of interelement capacities, resistances of the layers, etc, as well as the permissible deviations of all these parameters. This set of parameters was used in developing a system of automated designing of BIS, due to which they are constructed on the same element base, are designed according to identical rules, and must be manufactured under the same conditions.

Complexity of BIS. According to the performed evaluations, in order to ensure functional completeness of specialized BIS which would make it possible to manage with a limited nomenclature of circuits for constructing a wide class of machines, the latter had to have two-four times more transistors on a crystal than the most complicated BIS of the K145 series which were used

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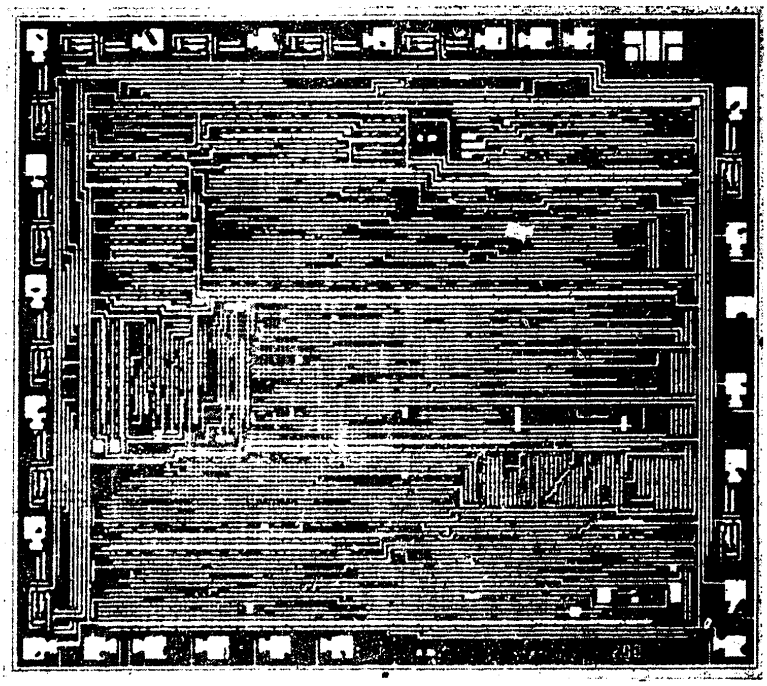
previously in the equipment of the ASPI complex. Considering the fact that a considerable increase in the dimensions of crystals can lead to unjustifiably high cost of production, measures were developed and implemented which doubled the density of the arrangement of transistors on crystals in comparison with the above-mentioned BIS of the K145 series.



The simplicity of the technology which is understood as the construction of the manufacturing process of BIS on the basis of the studied technological operations well assimilated in the USSR whose reproduction by a personnel not having sufficient production skills would be possible in a short time and with the equipment for which technological charts are compiled. In many instances, when developing a technology, rough indexes of circuits were given intentionally in order to lower the critical level of the technological process to the requirements imposed on the quality of initial materials, media, and the skills of the personnel, i.e., everything that always accompanies a new production during the period of its development.

Availability of Materials. When a fundamentally new production is created, its supply agencies are inevitably faced with the problem of providing

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materials which the enterprise did not use before. Therefore, in developing the technology, attempts were made to reduce the list of materials, to use only such brands and grades of materials which are being produced by the USSR industry, and to eliminate the use of imported materials from the very beginning.

Compatibility of Production. This term is understood to mean a complete electrical compatibility with respect to supply voltages, polarity, levels, and forms of input and output signals of specialized BIS with the IS of the above-mentioned series.

The technological process was based on a so-called standard high-threshold p-channel MOP [metal-oxide-semiconductor] technology with four basic cycles of photolithography. The minimum distance between the centers of any two neighboring elements was taken to be equal to 25 microns, the minimum width of the line and local gap between the boundaries of the elements was six microns, and the minimum size of the window was 6 x 6 microns. These dimensions correspond to a sufficiently high level of technology, however, they are still not too close to the limits imposed by the physical limitations or potentialities of the equipment.

Special attention was given to the reproducibility of the values of the threshold voltages of active and parasitic MOP transistors. For this, conditions of the chemical processing of the surfaces of silicone plates were studied in detail and selected at various stages of the process. The washing of plates in complex-forming compounds was used widely. A method of stabilizing the subgate oxide was developed thoroughly, including high-temperature annealing for gettering highly mobile ions. A high degree of ohmic resistance of the aluminum silicone contact has been achieved, and the assembly technology that was used ensures a very low value of the resistance of the substrate terminal, which is important for reliable operation of the circuits created on the basis of a dynamic four-cycle circuit technique with pulsed supply voltage.

On the basis of the technology developed under the conditions of experimental production, a number of specialized semiconductor assemblies with an integration within the limits of up to 4,000 transistors and crystal dimensions of up to 25 mm square have been created, manufactured, and introduced into series production.

The figure shows the topological structure of a logical arithmetic device on a crystal of 4.4 x 3.7 mm with 1712 transistors.

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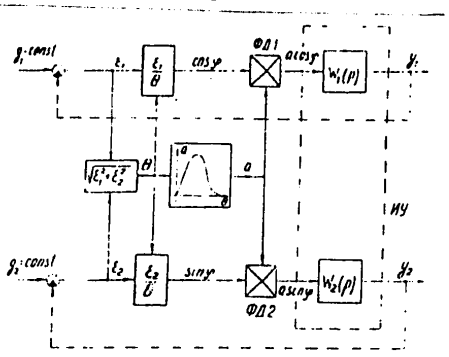
DETERMINATION OF CONDITIONS FOR ABSOLUTE STABILITY OF A RADAR TRACKING SYSTEM

Leningrad IZVESTIYA VUZOV SSSR: PRIBOROSTROYENIYE in Russian Vol 23, No 6, 1980 pp 23-28

[Article by L. B. Zor'yan, Leningrad Institute of Precision Mechanics and Optics]

[Text] Asymptotic stability of a radar tracking system is examined. Maximum angle of inclination of nonlinearity of a direction-finding device is determined, whereby the system is absolutely stable.

The problem of determining the absolute reliability of automatic control systems has been fairly widely investigated both on the basis of the Lyapunov direct method and with utilization of frequency criteria. Absolute stability of equilibrium position is defined as equilibrium position asymptotic stability in the Lyapunov sense with any characteristics of a nonlinear component belonging to a specified class.



Structural Diagram of a Radar Tracking System

In this article we shall examine, on the basis of Lyapunov's direct method, determination of the conditions of absolute stability of a two-channel

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bearing automatic tracking (ASN) radar system with sequential signal comparison (conical scanning) [see Bibliography], which is typical for angular tracking systems with amplitude-phase modulation.

A system structural diagram (see figure) has been prepared for the envelope of a carrier wave, on which: ε_1, ε_2 -- tracking errors in the azimuth and elevation planes; θ -- angular deflection of tracked target from equal-signal bearing (RSN); g_1, g_2 -- input disturbances describing target movement; y_1, y_2 -- angular coordinates of RSN.

An important feature of this system is the fact that it is single-channel up to phase detectors FD1, FD2. Amplitude (a) and phase (φ) of the signal voltage at phase detector input carry information on the polar coordinates of the target relative to RSN. Control voltages $u_1=a\cos\varphi$ and $u_2=a\sin\varphi$ are applied to the two-channel actuating device (IU).

The drive transfer functions applied to the IU have the form

$$W_1(p)=\frac{K_1}{p(1+a_1p+a_2p^2)},\quad W_2(p)=\frac{K_2}{p(1+b_1p+b_2p^2)}.$$

Functional dependence a=F(0) in the range $(0,\infty)$ satisfies condition

$$0<\frac{F(\theta)}{\theta}<\beta.$$

It is necessary to determine the maximum value β at which absolute stability in angle $(0,\beta)$ is observed.

The self-contained control system equations have the form

$$\begin{aligned}&K_1\frac{F(\theta)}{\theta}\varepsilon_1+\dot{\varepsilon}_1+a_1\ddot{\varepsilon}_1+a_2\dddot{\varepsilon}_1=0,\\&K_2\frac{F(\theta)}{\theta}\varepsilon_2+\dot{\varepsilon}_2+b_1\ddot{\varepsilon}_2+b_2\dddot{\varepsilon}_2=0,\\&\theta=\sqrt{\varepsilon_1^2+\varepsilon_2^2}.\end{aligned}\qquad(1)$$

We shall present system (1) in normal form, selecting as state variables

$$x_1=\varepsilon_1,\ x_2=\dot{x}_1,\ x_3=\ddot{x}_2,\ x_4=\varepsilon_2,\ x_5=\dot{x}_4,\ x_6=\ddot{x}_5.$$

Designating the coefficient of static linearization of nonlinear characteristic F(θ) by h(θ), we finally obtain

$$\begin{aligned}&\dot{X}=\Lambda X+\Phi(\theta,x_1,x_4),\\&\theta=\sqrt{x_1^2+x_4^2},\end{aligned}\qquad(2)$$

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where

$$X=\begin{Vmatrix} x_1 \\ \cdot \\ \cdot \\ \cdot \\ x_6 \end{Vmatrix},\quad A=\begin{Vmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & -c_1 & -c_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & -c_3 & -c_4 \end{Vmatrix},$$

$$\Phi(\theta,\ x_1,\ x_4)=\begin{Vmatrix} 0 \\ 0 \\ -K_1h(\theta)c_1x_1 \\ 0 \\ 0 \\ -K_2h(\theta)c_3x_4 \end{Vmatrix},$$

$$c_1=\frac{1}{a_1},\ c_2=\frac{a_1}{a_2},\ c_3=\frac{1}{b_2},\ c_4=\frac{b_1}{b_2}.$$

We shall write equations (2) in the form

$$\dot{X}=C[h_1'(\theta)]X$$
$$\theta=\sqrt{x_1^2+x_4^2}, \tag{2a}$$

where
$$C[h(\theta)]=\begin{Vmatrix} 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ -K_1h(\theta)c_1 & -c_1 & -c_2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -K_2h(\theta)c_3 & -c_3 & -c_4 \end{Vmatrix}.$$

To examine the asymptotic stability as a whole of equilibrium position X=0 of system (2), we shall write Lyapunov's function in quadratic form

$$V(X)=X^TQX,$$

where $Q=\begin{Vmatrix} Q_1 & 0 \\ 0 & Q_2 \end{Vmatrix}$, $Q_1=\|q_{ij}\|$ $(i, j=1, 2, 3)$, $Q_2=\|q_{ij}\|$ $(i, j=4, 5, 6)$

$$q_{ij}=q_{ji}.$$

Taking the time derivative of function V taking into account equation (2a), we obtain $\dot{V}(X)=\dot{X}^TQX+X^TQ\dot{X}=X^T[C^T(h)Q+QC(h)]X.$

We shall designate
$$C^T(h)Q+QC(h)=-L, \tag{3}$$

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then, without performing intermediate transformations, the condition of negative determinacy V(X) (positive determinacy of matrix L) reduces to positive determinacy of matrices

$$L_1 = \left\| \begin{array}{ccc} 2K_1c_1q_{13}h & -q_{11}+c_1q_{13}+K_1c_1q_{23}h & -q_{12}+c_2q_{13}+K_1c_1q_{33}h \\ -q_{11}+c_1q_{13}+K_1c_1q_{23}h & -2q_{12}+2c_1q_{23} & -q_{22}+c_2q_{23}-q_{13}+c_1q_{33} \\ -q_{12}+c_2q_{13}+K_1c_1q_{33}h & -q_{22}-c_2q_{23}-q_{13}+c_1b_{33} & -2q_{23}+2c_2q_{33} \end{array} \right\|, \quad (4)$$

$$L_2 = \left\| \begin{array}{ccc} 2K_2c_3q_{46}h & -q_{45}+c_3q_{46}+K^2c_3q_{56}h & -q_{45}+c_4q_{46}+K_2c_3q_{66}h \\ -q_{44}+c_3q_{46}+K_2c_3q_{56}h & -2q_{45}+2c_3q_{56} & -q_{55}+c_4q_{56}-q_{46}+c_3q_{66} \\ -q_{45}+c_4q_{46}+K_2c_3q_{66}h & -q_{55}+c_4q_{56}-q_{46}+c_3q_{66} & -2q_{56}+2c_4q_{66} \end{array} \right\|. \quad (5)$$

We shall designate the principal minors of the obtained matrices with $|L_{vm}|$ *v=1, m=1, 2, 3), where v -- number of matrix, m -- order of minor.

Then on the basis of Sylvester's criterion, matrices L_1 and L_2 can be considered positively determined if the following equalities are fulfilled:

$$|L_{vm}|<0 \quad (v=1, 2;\ m=1, 2, 3). \quad (6)$$

Considering that for first-order determinants inequalities (6) are always correct $\left(h=\frac{F(\theta)}{\theta}>0\right)$,

the condition of positive determinacy of matrices (4), (5) is reduced to system

$$-a_{vm}(q_v)h^2+b_{vm}(q_v)h+d_{vm}(q_v)>0 \quad (v=1, 2;\ m=2, 3), \quad (7)$$

where q_v -- sets comprised of elements of matrices Q_v.

We shall consider elements of matrices Q_1, Q_2 free parameters. Then for each set of values of elements of matrices Q_v there exist certain intervals for inclination of nonlinearity $F(\theta)$, in which inequalities (7) are correct. If we consider that transfer functions $W_1(p)$ and $W_2(p)$ define the system as not conditionally stable, the lower boundary of these intervals is equal to 0, which on the basis of (7) is correct when

$$d_{vm}(q_v)=0 \quad (v=1, 2;\ m=2, 3). \quad (8)$$

As follows from (4) and (5), equalities (8) are equivalent to the following relations:

$$q_{11}=c_1q_{13},\quad q_{12}=c_2q_{13},\quad q_{44}=c_3q_{46},\quad q_{45}=c_4q_{46}. \quad (9)$$

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On the basis of (8) and with angle of inclination of nonlinearity $h > 0$, inequalities (7) will assume the form

$$h < \frac{b_{vm}(q_v)}{a_{vm}(q_v)} = H_{vm}(q_v), \tag{10}$$

$$a_{vm}(q_v > 0 \quad (v=1, 2; \; m=2, 3). \tag{11}$$

We shall determine elements of matrices Q ensuring $\max_{q_V} H_{vm}(q_V)$ (v=1, 2; m=2, 3) under the condition of fulfillment of inequality (11). Calculating the maximum of functions H_{12}, H_{22} and one of the points of the extremum for H_{13} and H_{23}, taking (9) into account, we shall obtain the following relations between elements of matrix Q:

$$q_{11} = \frac{c_1^2}{2c_2} q_{23}, \; q_{12} = \frac{c_1}{2} q_{23}, \; q_{13} = \frac{c_1}{2c_2} q_{23}, \; q_{22} = \left(c_2 - \frac{c_1}{2c_2}\right) q_{23}, \; q_{33} = \frac{2}{c_2} q_{23},$$

$$q_{44} = \frac{c_3^2}{2c_4} q_{56}, \; q_{45} = \frac{c_3}{2} q_{56}, \; q_{46} = \frac{c_3}{2c_4} q_{56}, \; q_{55} = \left(c_4 - \frac{c_3}{2c_4}\right) q_{56}, \; q_{66} = \frac{2}{c_4} q_{56}. \tag{12}$$

Substituting (12) in (10) and (11), we obtain:

$$h < H_{12} = H_{13} = \frac{c_1}{K_1 c_2}, \; h < H_{22} = H_{23} = \frac{c_3}{K_2 c_4}; \tag{13}$$

$$c_2^2 - 2c_1 > 0, \; c_4^2 - 2c_3 > 0. \tag{14}$$

Quantity $\beta_{max} = \min\left\{\frac{c_1}{K_1 c_2}, \frac{c_3}{K_2 c_4}\right\}$ determines the maximum inclination of nonlinearity ensuring specific negativity of $\dot{v}(X)$ in angle $(0, \beta_{max})$.

We shall check the positivity of matrices Q_1 and Q_2, for which we shall write their principal minors of the second and third orders:

$$|Q_{12}| = c_1^2(c_2^2 - c_1), \quad |Q_{13}| = \frac{c_1^2}{4c_2^3}(c_2^2 - 1{,}5c_1),$$

$$|Q_{22}| = c_3^2(c_4^2 - c_3), \quad |Q_{23}| = \frac{c_3^2}{4c_3^3}(c_4^2 - 1{,}5c_3).$$

As is evident from the obtained expressions, minors Q_1 and Q_2 are also positive in fulfilling conditions (14).

Thus for Lyapunov's function of type $V(X)=X^TQX$ those elements of matrix Q are determined which ensure a maximum for inclination

$$h(\theta) = \frac{F(\theta)}{\theta},$$

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whereby the system is absolutely stable at angle (o, β_{max}) (with limitations (14) on system parameters). The obtained sufficient conditions of absolute stability make it possible to synthesize a radar tracking system which ensures lock-on when transitioning to automatic tracking.

In conclusion we should note that conditions (14) are fulfilled for a broad class of automatic control systems:

1) $W_1(p) = \frac{K_1}{p(1+T_1p)(1+T_2p)}$ -- sequential combination of an integrating and aperiodic element of the second order,

$$c_2^2 - 2c_1 = \frac{a_1^2 - 2a_2}{a_2^2} = \frac{T_1^2 + T_2^2}{T_1^2 T_2^2} > 0;$$

2) $W_1(p) = \frac{K_1}{p(1+2\xi Tp+T^2p^2)}$ -- sequential combination of integrating and oscillating element,

$$c_2^2 - 2c_1 = \frac{T^2(4\xi^2-2)}{T^4} > 0$$

when $\xi > 0.71$.

When condition (14) is not fulfilled, we can place in matrices L_1 and L_2

$$-q_{22} + c_2 q_{23} - q_{13} + c_1 q_{33} = 0, \quad -q_{55} + c_4 q_{56} - q_{16} + c_3 q_{66} = 0.$$

Then $$\beta_{max} = \min\left\{\frac{c_1 c_2}{K_1(c_2^2 + 2c_1)}, \frac{c_3 c_4}{K_2(c_4^2 + 2c_3)}\right\}.$$

Elements of matrix Q are determined from the following equalities:

$$q_{11} = \frac{c_1^2}{2c_2} q_{23}, \quad q_{12} = \frac{c_1}{2} q_{23}, \quad q_{13} = \frac{c_1}{2c_2} q_{23}, \quad q_{22} = \frac{3c_1 + 2c_2^2}{2c_2} q_{23}, \quad q_{33} = \frac{2}{c_2} q_{23},$$

$$q_{44} = \frac{c_3^2}{2c_4} q_{56}, \quad q_{45} = \frac{c_3}{2} q_{56}, \quad q_{46} = \frac{c_3}{2c_4} q_{56}, \quad q_{55} = \frac{3c_3 + 2c_4^2}{2c_4} q_{56}, \quad q_{66} = \frac{2}{c_4} q_{56},$$

no limitations are imposed on the values of system parameters.

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